The Research on the Change of Wind Speed on the Upper Wind Direction of Wind Turbine

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Abstract. The aerodynamic performance analysis of the air flow through the cross section of the wind turbine and the simulation of different wind speed values of the wind turbine blades before and after convection prove that the wheel anemometer is placed directly on the center of fan blade to collect the information of wind speed and direction is feasible. Simulation test of wind speed change at a sampling point of wind turbine shows that the change value of the wind speed at the fixed point of the blade varies with the position of the rotation of the blade. Therefore, the wind speed is different from the wind turbine blade, and it will bring some influence to the wind speed measurement.

Introduction

Wind energy, as a kind of clean renewable energy, has attracted more and more attention from all over the world in recent years. With the increasing maturity of wind power generation technology, To improve the accuracy of wind speed detection become more and more essential. And accurate wind speed is very important to control the power level of the fans. The pitch angle control method is an effective means to regulate the wind power output level which controls the output power of the wind turbine by the direct control of the aerodynamic load[1]. Due to the strong nonlinearity of wind turbine model, in order to reduce the difficulty of control, most of the pitch angle controller are based on the linear model of the fan. However, the performance of this controller is severely reduced when the operating point of the fan is deviated from its linear point[2].In order to solve the above problems, a variable gain controller is designed whose controller gain can changed when the operating point of the fan changed[3,4].But the method needs to know the wind speed of the wind turbine blade, however, however, the actual wind speed wind speed measurement instrument is generally located in the fan head wind zone. Due to the influence of the tower shadow effect and the wake effect, the wind speed measured and the wind speed of the wind turbine blades have a certain difference, which increases the application difficulty of the method[5]. One pole placement method of proportional integral differential pitch controller is designed in paper [6]. However, when the fan operating point deviates from its linearization point, the performance of the controller is seriously reduced, and even cause the instability of the system. The industrial use of the Calman filter PI controller, fuzzy controller and the optimal controller yaw control signals are derived from the wind speed sensor[7].Due to the wind speed sensor is located under the wind direction, by a variety of adverse factors such as turbulence, and its
measurement accuracy is not enough, so that the accuracy of wind speed measurement is not high enough.

In this paper, the theoretical research and simulation of wind speed of wind turbine blade with wind direction and wind speed are studied which confirmed this difference by the wind and the wind speed at the leeward. And the difference is even more obvious when it approaches the wind round. In addition, due to the wind shear effect, the wind speed of the center position of the wind turbine blade is different from that of the other position of the blade. the average wind speed at the center position of the wind wheel can obtained from the change curve of the rotating sampling points in the swept surface of the wind wheel, thereby reducing the error of the measurement.

Study on Wind Direction and Wind Speed of Wind Turbine Blades

As is shown in Fig.1, numerical simulation of air flow around wind turbine in wind turbine, the solution area \( \Omega \) is a cylindrical solution area including the wind wheel. Solution areas include two parts of the inlet area \( \Omega_1 \) and outlet \( \Omega_2 \) (Eq.1). The boundary \( \Gamma_1 \) is the outer surface of the solution region, \( \Gamma_2 \) is the interface between the entrance region and the interface.

\[
\Omega_1 = \{(x, r, \theta) | X1 \leq x \leq 0, 0 \leq r \leq R1, 0 \leq \theta \leq 2\pi\}
\]
\[
\Omega_2 = \{(x, r, \theta) | 0 \leq x \leq X2, 0 \leq r \leq R1, 0 \leq \theta \leq 2\pi\}
\]  

(1)

The solving area is a cylinder, so the mathematical model of the wind field around the wind generator is more simple and convenient by using the cylindrical coordinate system.

The cylindrical region is used to simulate the airflow in the vicinity of the wind turbine, and the definite conditions (Eq.2) of the governing equations in the cylindrical coordinate system are

\[
\Gamma_3 = \{(x, r, \theta) | x = 0; r \leq R_0; \alpha + \frac{2k\pi}{3} - \frac{\alpha}{2} \leq \theta \leq \alpha + \frac{2k\pi}{3} + \frac{\alpha}{2}, k = 0, 1, 2\}
\]  

(2)

In the formula, \( R_0 \) is the length of the wind turbine blade; \( C \) is the length of the blade;

\( \Gamma_1 \) satisfies the boundary condition (Eq.3)

\[
\mathbf{V} = \mathbf{V}_0, \quad \rho = \rho_0
\]  

(3)

\( \Gamma_2 \cap \Gamma_3 \) meets the boundary condition (Eq.4)

\[
\begin{align*}
    u &= 0, \quad \frac{\partial v}{\partial x} = 0, \quad \frac{\partial w}{\partial x} = 0, \\
    \frac{\partial \rho}{\partial x} &= \frac{\rho}{RT} f_x = \frac{-2\rho^2 v_0^3 a(1-a)A}{RT}
\end{align*}
\]  

(4)

Supplementary boundary conditions (Eq.5)
\[
\lim_{r \to 0^+} r \frac{\partial u}{\partial r} = 0, \quad \lim_{r \to 0^+} r \frac{\partial v}{\partial r} = 0
\]
\[
\lim_{r \to 0^+} r \frac{\partial w}{\partial r} = 0, \quad \lim_{r \to 0^+} r \frac{\partial \rho}{\partial r} = 0
\]

(5)

Initial condition (Eq. 6) is
\[
V = V_0, \quad \rho = \rho_0
\]

(6)

among: \( \rho_0 \) is for the initial air density, \( A \) is for wind turbine swept area, \( \alpha \) is for the axial induction factor, \( \omega \) is the size of the angular velocity vector, \( V_0 \) is for the infinite wind speed, \( v_0 = |V_0| \).

In summary, the value problems for systems of partial differential equations can be found by equation (1), the initial conditions and boundary conditions.

![Figure 1. Mathematical model of wind speed.](image)

**Effective Wind Speed Simulation**

Effective wind speed values depend on the load considered. The effective wind speed of the pneumatic matrix is different from the effective wind speed of the thrust force. The effective wind speed simulation uses the Eq. 7, Eq. 8 and Eq. 9 to simulate the turbulence of the wheel hub.

\[
V_m(t) = V_0 + \sum_{i=1}^{m} A_i \cos(\omega t + \zeta)
\]

(7)

\[
V(t) = \delta \cdot \omega_c(t)
\]

(8)

\[
H_f(i\omega) = \frac{K_\chi (i\omega T, a_1 + 1)}{(i\omega T, + 1)(i\omega T, a_2 + 1)}
\]

(9)

As the effective wind speed is a kind of average wind speed over the swept surface of the impeller, the effective wind speed is more stable than any fixed point wind speed change. Wind energy is the power source of the energy conversion of wind power generation unit, and the size and direction of the stroke in nature are constantly changing. So wind power generation system model must take full account of the various wind conditions that may occur during the operation of the unit, and the dynamic model can be more perfect and accurate. It can be seen from the wind speed modeling process, the mathematical model of the wind speed change needs to know the location of the wind turbine to determine the average wind speed. Then, the numerical simulation and analysis of the effective wind speed which affect the operation of the generator unit is carried out according to the IEC code.
Fig. 2 describes the Eq.7 of the effective wind speed signal.

![Figure 2. Simulation of effective wind speed signal.](image)

**Aerodynamic Performance of Wind Turbine Before and After Sweeping**

In order to verify the influence of variable pitch control of wind turbine on the aerodynamic characteristics of the wind turbine, according to the steady condition of the mathematical model of the wind speed in the cylindrical coordinate system, Pitch angle is selected and the computer simulation to calculate the along wind wheel wind speed changes drawn out by the origin. The simulation results are shown in Fig. 3.

Take the curve 2 as an example, about 10m after the wind wheel sweep in front of the wind, wind speed attenuation is most rapid. The upper reaches of wind speed is 13m/s the speed of wind wheel sweep is only 11m/s. Wind speed at the section of the wind turbine is only 8m/s. In the distance from the wind wheel section, the wind speed attenuation range is not big, and finally tends to a fixed wind speed value. The traditional fan wind instrument is about 5m behind the swept surface of fan, the wind speed is about 10m/s, is smaller than the wind wheel section. Comparing the two curves, when the pitch angle is large, the speed difference will be greater.

![Figure 3. The air flow through the section of the wind turbine.](image)

The wind speed in the center position of the wind wheel is 12m/s, superimposed random wind speed is 0-2m/s, the distance from the sampling point to the origin is 17m, and the speed change curve of rotating sampling rotate with 20r/min. It can be seen from the curve of the
wind speed in the graph, when the wind turbine blade rotates at a close to the rated speed, the change of the wind speed at the fixed point of the blade is changed with the change of the position of the blade rotation. The mathematical expression formula (Eq. 10) of wind speed on the surface of wind turbine blade is

\[
V_1(t) = V(r, \theta, t) \\
V_2(t) = V(r, \theta + 120^\circ, t) \\
V_3(t) = V(r, \theta - 120^\circ, t)
\]

among: \( r \) is the distance between any point on the blade surface and the center of the wind wheel; \( \theta \) is the included angle between the selected point and the origin of the wind wheel; \( V_1, V_2, \) and \( V_3 \) were the values of wind speed on the blades.

The wind speed at the sampling point at the center of the wind turbine is roughly as shown in Fig. 4. At the center the wind speed is 12 m/s, and the minimum speed is about 11 m/s, the maximum speed is about 13 m/s. The cycle of this curve is about 3 s. That is to say, the wind speed varies with time in any one of the positions of the plasma. And at the center of the wind wheel, the rotating radius is 0, the sampling point is constant from the ground, and the wind speed is stable at a certain speed.

![Figure 4. Variation curve of sampling point in swept surface of wind turbine.](image)

**Conclusions**

1. According to the fan blade wind direction and wind speed simulation, theoretical study and Simulation of gas dynamic analysis shows that the wind speed in the section of the wind turbine is very large and the wind speed at the windward and leeward are different;
2. Research from the fan wheel hub center 17 m at blade wind swept in-plane rotation sampling point curves show: wind speed in the sinusoidal oscillating variation process is not suitable for the detection of wind speed;
3. As the effective wind speed is a kind of average wind speed over the swept surface of the impeller, the effective wind speed is more stable than any fixed point wind speed change, and
the mathematical model of the wind speed change needs to know the location of the wind turbine to determine the average wind speed value.

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References


